Tetrahedron Letters No.16, pp. 1053-1058, 1965. Pergamon Press Ltd.
Printed in Great Britain.

CONJUGATIVE 1.5-ADDITION OF ORGANIC ACIDS TO ACTIVATED VINYLCYCLOPROPANES

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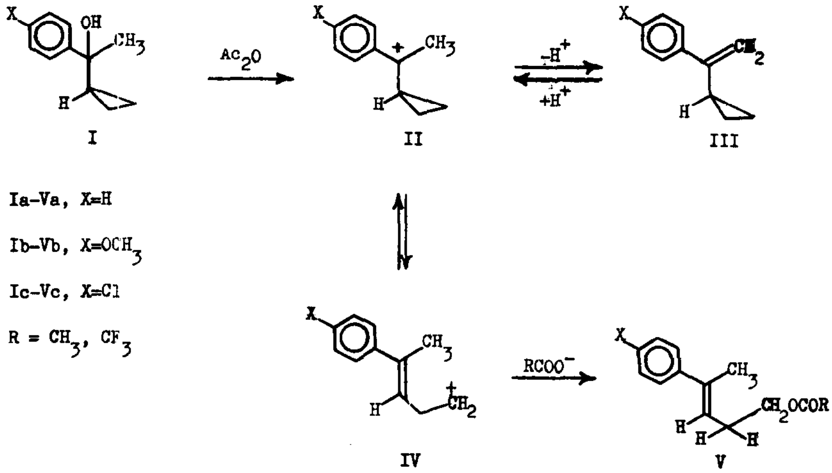
(Received 20 January 1965; in revised form 24 February 1965)

In a previous paper[1] it has been suggested that the formation of the two products: α-cyclopropylstyrenes (III) and 4-arylpent-3-enyl acetates (V), resulting from the acetic anhydride-promoted dehydration of methylarylcyclopropylcarbinols (I), involves a common carbonium-ion intermediate of the structure II, which is at equilibrium with both the homoallylic carbonium-ion, IV, and the olefine, III[2]. This communication presents evidence substantiating the above proposed reaction mechanism, and shows that vinylcyclopropanes, properly activated by aryl substituents, can enter into addition reactions with unsymmetrical molecules, such as acetic and trifluoroacetic acids, to yield adducts of the <u>cis</u>-structure (Va - Vc, R=CH_3, CF_3), involving a conjugative cyclopropane ring-opening. Although a similar mode of acid-catalysed addition has previously been reported in the steroid field[3], this work provides, to our knowledge, the first demonstration of an uncatalysed reaction in simpler models of vinylcyclopropane[4].

A solution of III (one mole) in glacial acetic acid (10 moles) was refluxed for 90 min. and then fractionally distilled at reduced pressure. The addition of trifluoroacetic acid to IIIa - IIIc requires milder conditions in order to minimise polymerisation. To a solution of III (one mole) in five volumes of carbon tetrachloride was added dropwise equimolar quantity of trifluoroacetic acid, at 0°, and then processed in the usual way.



Ia-Va, X=H

Ib-Vb, X=OCH_3

Ic-Vc, X=Cl

R = CH_3, CF_3

TABLE 1

The Effect of Substituents on Additions of Acetic Acid to IIIa - IIIc

Substrate	4-Arylpent-3-enyl acetate % yield	Polymeric Products % yield	Olefin Recovery % yield
IIIa	70	12	18
IIIb	80	20	0
IIIc	45	10	45

TABLE 2

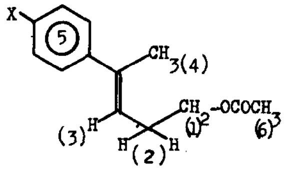
4-Arylpent-3-enyl Trifluoroacetates From III → V Conversions

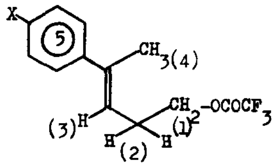
Compd.	Yield %	Polymeric Products % yield	B.P. °C	$\bar{\nu}$(CO) cm^{-1}	$\bar{\nu}$(CF_3) cm^{-1}	λ_{max} mμ	ε
Va	13	78	76-78 (0.2 mm)	1800	1125-1366	243	11500
Vb	15	80	145-148 (0.1 mm)	1805	1174-1311	226 251	9555 5100
Vc	51	38	96 (0.1 mm)	1810	1110-1271	249-250	15000

The known acetates[1] (IIIa - IIIc, R=CH_3) were easily characterized by means of physical properties, the infrared and ultra-violet spectra, the nmr spectrum and gas chromatographic analysis. The unknown trifluoroacetates (IIIa - IIIc, R=CF_3) were characterized, in addition to the above, also by elementary analysis. The yields and properties are given in Tables 1 and 2, and the nmr data in Table 3.

TABLE 3

NMR Signals of 4-Arylpent-3-enyl Acetates and Trifluoroacetates[a]





	Chemical Shifts (p.p.m.)	Relative intensities	Splitting	Chemical Shifts (p.p.m.)	Relative intensities	Splitting
$H_{(1)}$	4.14–4.25	2	triplet	4.42-4.43	2	triplet
$H_{(2)}$	2.51-2.58	2	double triplet	2.62-2.66	2	double triplet
$H_{(3)}$	5.73–5.78	1	triplet	5.63–5.67	1	triplet
$H_{(4)}$	2.02-2.09	3	singlet	2.01-2.07	3	singlet
$H_{(5)}$	7.23–7.32	b	c	7.10–7.31	b	c
$H_{(6)}$	2.02-2.09	3	singlet	-	-	-

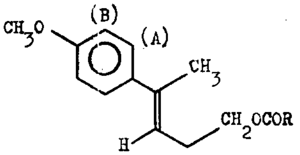
$J_{H(3),\ CH_3} = 2$ cps $J_{H(3),\ CH_3} = 2$ cps

[a] The NMR spectra in $CDCl_3$ were obtained on a Varian A-60 spectrometer. Peak positions are given as parts-per-million (ppm) downfield from tetramethyl silane as internal standard. [b] Values of 5 and 4 were obtained for Va and Vb-Vc, respectively. [c] Appearing as a multiplet in Va, as a A_2B_2 type quartet in Vb (centered: at 7.23 ppm for R=CH_3; at 7.10 ppm for R=CF_3), and in Vc as a single peak.

An examination of the nmr spectra of substrates (IIIa-IIIc) and of products resulting from their interaction with acetic and trifluoroacetic acids (Va - Vc, R=CH_3, CF_3) clearly indicate that the III → V conversion is accompanied by the disappearance of the cyclopropane protons (centered at 0.69 and 1.56 ppm in IIIa - IIIc) and the terminal vinylic protons (appearing as singlets at 4.92 and 5.25 ppm) and the appearance, instead, of six protons assignable to two methyl groups (singlet), and four aliphatic protons assignable to two acyclic methylene groups (appearing as triplets), causing no essential change in the aromatic region of the spectrum. The aromatic protons in Vb (R=CH_3, CF_3) are of the A_2B_2 system, typical for para disubstituted benzenes[5]. The positions of the A and B bands were calculated from the four AB principal signals[6], and the $\delta_A - \delta_B$ differences were calculated for the assignment of the geometry of the double-bond[7].

TABLE 4

$\delta_A - \delta_B$ Values of 4-(p-anisyl)-pent-3-enyl Acetate and Trifluoroacetate[a]



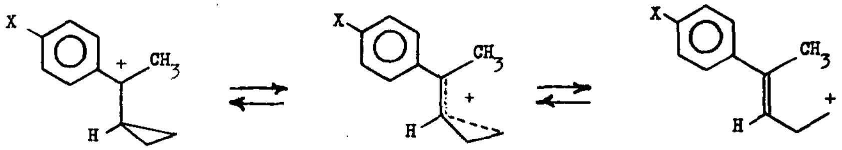
R	A	B	$\delta_A - \delta_B$
CH_3	447.5	420.5	27.0
CF_3	439.4	412.6	26.8

[a] Values expressed in cps

From the observed $\delta_A - \delta_B$ values (Table 4), it was possible to assign a <u>cis</u> relationship to the alkyl groups in Vb[8], following the work of Barbieux, Defay, Pecher, and Martin[7] who showed recently that in α,β-disubstituted para methoxy styrenes the $\delta_A - \delta_B$ values are 25-30 cps for the *cis*-isomers and 13-16 cps for the *trans*-isomers. In view of identity in the $J_{H_{(3)},CH_3}$ values of Va-Vc

($R=CH_3,CF_3$), and their homogeneity in the vapor-phase chromatography, it is plausible to assign a cis geometry also to Va and Vc, as in Vb.[9].

From the data presented here one can conclude that the addition of the aliphatic acids to the vinylcyclopropane systems (IIIa-IIIc) proceeds in the conjugative 1.5-manner (III $\rightarrow$ II $\rightarrow$ IV $\rightarrow$ V), leading selectively to the formation of a single geometrical isomer, in which the methyl and the emerging β-acetoxyethyl groupings are cis related. It is significant to note that similar stereospecifici· has been also observed by Julia and coworkers[10] in the homoallylic rearrangement of ethinylcyclopropyl carbinol. This suggests a preferred cis geometry for the methyl and cyclopropyl groups in the transition state (VI) for the reversible rearrangement of the protonated substrate, II, into the homoallylic carbonium-ion, IV, due to eclipsing effects which appear to be smaller for the methyl than for the aryl groups[11].



II VI IV

In the additions of acetic acid to IIIa-IIIc, the relative order of the effect of substituents in the phenyl group on the extent of reaction is $CH_3O > H > Cl$. This can be explained in terms of variations in the basicities of the respective olefins and/or the stability of the resulting carbonium-ion (II), due to the polar effect of substituents in the phenyl group.

In the reactions with a much stronger acid, trifluoroacetic acid, reasonable yields could be obtained only with the least basic substrate, IIIc. This arises probably from a concurrent polymerisation reaction, which occurs to a larger extent in case of IIIa and IIIb, resulting in a drop in the yields of the desired products (Va and Vb, R=CF_3).

Acknowledgement. We wish to thank Dr. Yuval Shvo, of the Department of Organic Chemistry, Weizmann Institute of Science, Rehovot, for the NMR measurements.

REFERENCES

1. S.Sarel and E.Breuer, *Israel J.Chem.*, **1**, 451 (1963)
2. This was based on the observation of extensive variation in III/V ratio, depending on whether the acetic acid, formed in the course of reaction, being present or absent from the reaction mixture. Thus, the IIIb/Vb varies from 34:45 in the former case, to 84:11 in case the acetic acid was removed as it formed.
3. B.Riegel, G.P.Hager and B.L.Zenitz, *J.Amer.Chem.Soc.*, **68**, 2562 (1946).
4. This amplifies a previous finding indicating 1,5-cycloaddition of maleic anhydride to IIIa, S.Sarel and E.Breuer, *J.Amer.Chem.Soc.*, **81**, 6522 (1959).
5. J.Martin and B.P.Bailey, *J.Chem.Phys.*, **37**, 2594 (1962). R.E.Richards and T.P.Schaeffer, *Trans.Faraday Soc.*, **54**, 1280 (1958).
6. L.M.Jackman, "Application of Nuclear Magnetic Resonance Spectroscopy in Organic Chemistry", p.89, Pergamon Press, London, 1959.
7. M.Barbieux, N.Defay, J.Pecher and R.H.Martin, *Bull.Soc.Chim.Belges*, **73**, 716 (1964).
8. We wish to express our gratitude to Professor R.H.Martin for referring to his recent findings[7], which proved to apply successfully in this study.
9. The long-range allylic coupling constants, $J_{H_{(3)},CH_3}$=2 cps are in keeping with the assigned structures. Compare, ref.7, and D.J.Collins, J.J.Hobbs, and S.Sternhell, *Aust.J.Chem.*, **16**, 1030 (1963). See also, S.Sternhell, *Rev.Pure Appl.Chem.*, **14**, 15 (1964).
10. M.Julia, S.Julia, B.Stalla-Bourdillon, and C.Descoins, *Bull.Soc.Chim.France*, 2533 (1964).
11. See, D.J.Cram in M.S.Newman's "Steric Effects in Organic Chemistry", Chapman and Hall, Limited, London, 1956, p.273-274.